AFFDL-TM-73-3-FBC

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AIR FORCE FLIGHT DYNAMICS LABORATORY
DIRECTOR OF LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT PATTERSON AIR FORCE BASE OHIO

AF FLIGHT DYNAMICS LABORATORY

USER'S INSTRUCTIONS FOR COMPUTER PROGRAMS

JTSDL (Single & Double Lap Bonded Joints)
JTSTP (Step Lap Bonded Joints)

Prepared by

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T. J. Muha

Technical Memorandum FBC-73-3

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FOREWORD

This work was conducted by Mr P. C. Carroll and Mr T. J. Muha, Exploratory Development Group, Advanced Composites Branch, at the Air Force Flight Dynamics Laboratory, under Project 4364, "Filamentary Composites Structures," "Bonded Joint Analysis."

The manuscript was released by the authors in January 1973. This Technical Memorandum has been reviewed and is approved.

Philip A. Parmley

PHILIP A. PARMLEY
Chief, Advanced Composites Branch
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PART I

GENERAL INFORMATION

1.1 Program Titles

This Technical Memorandum covers the input required to run two computer programs. The first program, JTSDL, analyzes single or double lap bonded joints. The second program, JTSTP, analyzes step lap bonded joints.

1.2 Background

These programs were written by Southwest Research Institute under contract F33615-69-C-1641 with AFFDL/FBC. The results of this contract are published in AFFDL-TR-72-97. Copies of the computer programs are available from AFFDL/FBC, Wright-Patterson AFB, Ohio 45433, Attn: Mr. T. Muha or Mr P. Carroll.

1.3 Program Descriptions

These programs deal with the nonlinear analysis of bonded joints subjected to static loads at room temperature. The joints are assumed sufficiently wide in the z-direction (perpendicular to the plane shown in Figures 1.1 - 1.3) so that a state of plane strain exists. The adherends may be either orthotropic (laminates) or isotropic, with each adherend having its own constant thickness. The adhesive is assumed to be isotropic with constant thickness. Normal stresses through the thickness and interlaminar shear are neglected. Also, each laminate is assumed to be symmetrical about its middle surface.

1.4 Definitions

The following nomenclature is used in this memorandum and in AFFDL-TR-72-97:

ν = Poissons's Ratio

G = Shear Modulus

E = Young's Modulus

m,n = Shape Parameters

σ_o = Secant Yield Stress

1 = Longitudinal Direction

t = Transverse direction, in Plane of Lamina

x = Direction Along Joint Length

y = Direction Normal to Plane of Joint

1.5 Joint Geometries

The three joints, along with the coordinate systems, dimensions, and applied loads which are analyzed by these programs are shown in the following three figures.

Figure 1-1 Single Lap Joint

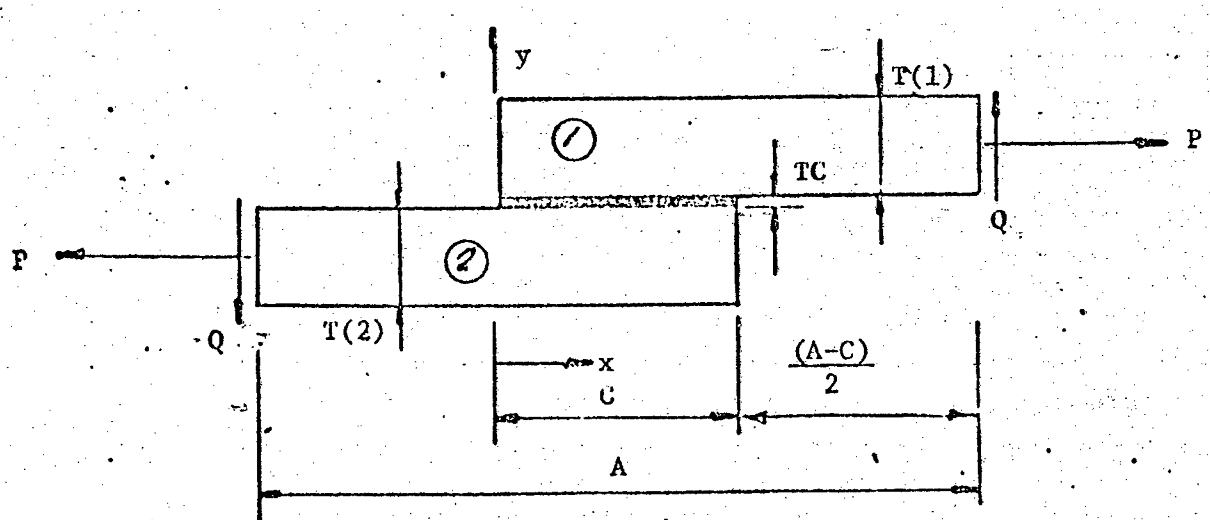


Figure 1-2 Double Lap Joint

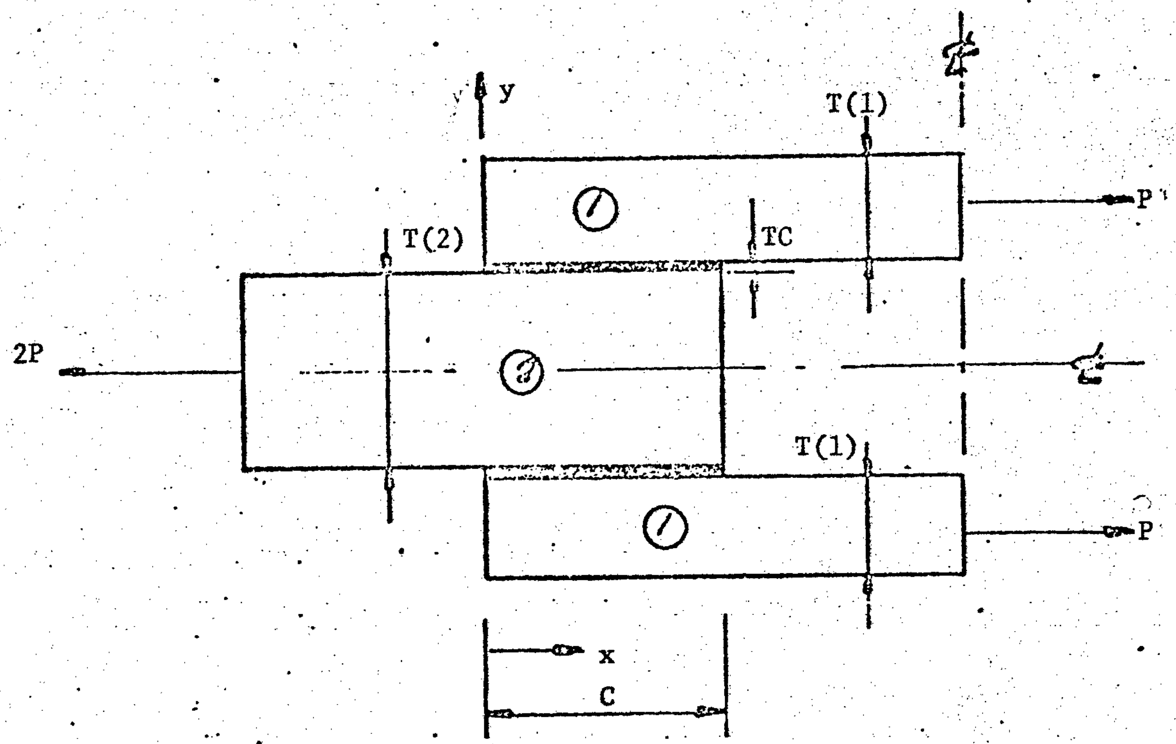
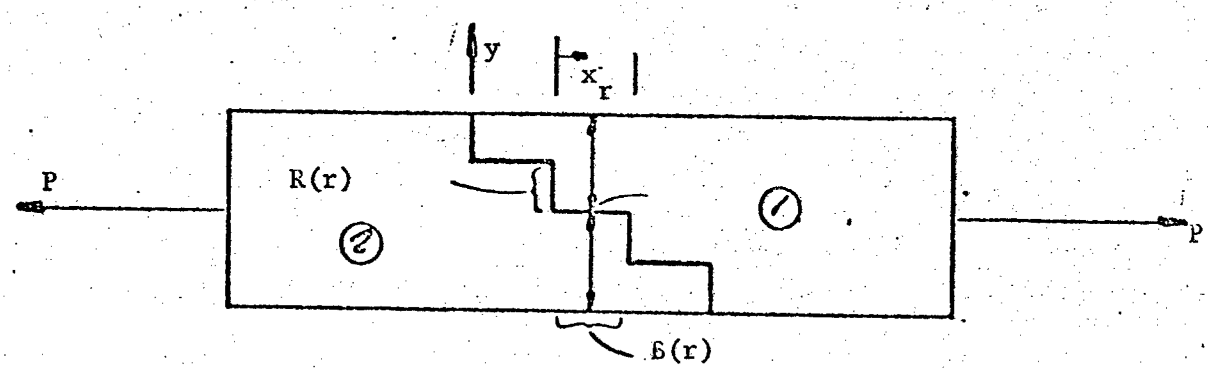


Figure 1-3 Step Lap Joint



Typical for step r
R steps in general (3 shown)

PART II

JTSDL INPUT

The input for the nonlinear analysis of single and double lap joints consists of ten logical cards. A logical card may consist of more than one actual, physical card. In the following explanation, a logical card will be referred to as a card.

CARD 1: TITLE CARD

COLUMNS	FORMAT	VARIABLE	EXPLANATION
1-70	10A7	Title	Any alphanumeric information
71-80	I10	KTYPE	Type of Joint: 1, for single lap, 2, for double lap

CARD 2: GEOMETRY, LOAD, ITERATION LIMITS

COLUMNS	FORMAT	VARIABLE	EXPLANATION
1-10	F10.0	A	Total length of joint (See Fig 1-1)
11-20	F10.0	C	Joint bond length (See Fig 1-1)
21-30	F10.0	P	Joint load (If P=0, the program will compute joint ultimate load)
31-40	F10.0	XERR	Iteration error - left up to user's discretion (For SwRI value, see Appendix)
41-50	I10	NIT	Maximum number of iterations - left up to user's discretion (For SwRI value, see Appendix)
51-60	I10	N	Number of stations for numerical integration - left up to user's discretion (For SwRI values, see Appendix)

COLUMNS	FORMAT	VARIABLE	EXPLANATION
61-70	I10	NP	Flag for printing adherend stresses:
			0, Print
			1, Do not print
71-80	F10.0	EFFK	Effective Bending Factor (See Appendix)

NOTE: The user should carefully note the values of the correction factor EFFK suggested in the Appendix when assessing the desirability of using this program to solve his particular problems. (See Pages 146-149 of AFFDL-TR-72-97)

CARD 3: ADHESIVE PROPERTIES (ISOTROPIC)

COLUMNS	FORMAT	VARIABLE	EXPLANATION
1-10	F10.0	TC	Thickness
11-20	F10.0	VC	Poisson's Ratio
21-30	F10.0	GC	Shear Modulus
31-40	F10.0	ESC	See Appendix
41-50	F10.0	ENC	See Appendix

CARD 4: GEOMETRY OF ADHEREND 1

COLUMNS	FORMAT	VARIABLE	EXPLANATION
1-10	F10.0	T	Total Thickness
11-14	I4	NL	Number of layers (Maximum of 61, 1 IF isotropic adherend)
15-79	13F5.0	ORNT(1,J)	Fiber orientation in degrees for each layer (Omit if isotropic)

If more than 13 layers, continuation cards of format 16F5.0 are used.

CARD 5: ADHEREND 1 - LAMINA PROPERTIES

A. (Used for Laminated Materials Only)

COLUMNS	FORMAT	VARIABLE	EXPLANATION
1-20	F20.0	E(1,1)	E_1 (See Appendix)
21-30	F10.0	ES(1,1)	σ_1 (See Appendix) - Omit for linear curve
31-40	F10.0	EN(1,1)	n_ℓ (See Appendix) - Omit for linear curve
41-60	F20.0	E(1,2)	$-E_1/\nu_{1t}$ (See Appendix)
61-70	F10.0	ES(1,2)	σ_{1t} (See Appendix) - Omit for linear curve
71-80	F10.0	EN(1,2)	n_{1t} (See Appendix) - Omit for linear curve

B. (Used for Isotropic Homogeneous Materials Only)

COLUMNS	FORMAT	VARIABLE	EXPLANATION
1-20	F20.0	E(1,1)	E
21-30	F10.0	ES(1,1)	σ (See Appendix) - Omit for linear curve
31-40	F10.0	EN(1,1)	n (See Appendix) - Omit for linear curve
41-50	F10.0	VA(1)	ν

CARD 6: CONTINUATION OF CARD 5A

COLUMNS	FORMAT	VARIABLE	EXPLANATION
1-20	F20.0	E(1,3)	E_t (See Appendix)
21-30	F10.0	ES(1,3)	σ_t (See Appendix) - Omit for linear curve
31-40	F10.0	EN(1,3)	n_t (See Appendix) - Omit for linear curve
41-60	F20.0	E(1,4)	G_{1t} (See Appendix)
61-70	F10.0	ES(1,4)	τ_{1t} (See Appendix) - Omit for linear curve
71-80	F10.0	EN(1,4)	m_{1t} (See Appendix) - Omit for linear curve

NOTE: For an isotropic adherend, there is no Card 6.

CARDS 7, 8, & 9: ADHEREND 2

Cards 7, 8, & 9 are repeats of Cards 4, 5, & 6 using Adherend 2 data.

CARD 10: ALLOWABLES FOR ULTIMATE STRENGTH PREDICTION (See Note Below)

COLUMNS	FORMAT	VARIABLE	EXPLANATION
1-2	I 2	KFAILC	Failure criterion for the adhesive (See Appendix)
3-12	F10.0	SC=SU	Allowable shear stress (strain) for the adhesive
13-14	I2	KFAIL(1)	Failure criterion for Adherend 1 (See Appendix)
15-24	F10.0	STRSLF(1)	Allowable long. stress (strain) in Adherend 1
25-34	F10.0	STRSTF(1)	Allowable trans. stress (strain) in Adherend 1
35-44	F10.0	STRSLTF(1)	Allowable shear stress (strain) for Adherend 1
45-46	I2	KFAIL(2)	Failure criterion for Adherend 2 (See Appendix)
47-56	F10.0	STRSLF(2)	Allowables for Adherend 2
57-66	F10.0	STRSTF(2)	Allowables for Adherend 2
67-76	F10.0	STRSLTF(2)	Allowables for Adherend 2

NOTE: This card is input only if P=0 on Card 2; if P≠0, omit Card 10.

PART III

JTSTP INPUT

The input for the nonlinear analysis of step lap bonded joints is identical to the input for JTSDL, except as noted below.

<u>CARD 1</u>

Omit the variable KTYPE.

<u>CARD 2</u>

Replace this card with the following cards:

<u>CARD 2A</u>: <u>Geometry</u>, <u>Load</u>, <u>and</u> <u>Iteration</u> <u>Limits</u>

COLUMNS	FORMAT	VARIABLE	EXPLANATION
1-10	I10	NS	Number of steps
11-20	F10.0	P	Loads
21-30	F10.0	XERR	Iteration error tolerance
31-40	I10	NIT	Maximum number of iterations
41-50	I10	N	Number of stations for numerical integration
51-60	I10	NP	Adherend stresses print flag
			0, Print
			1, Do not print
61-70	F10.0	EFFK	Effective bending factor (See Appendix)

CARD 2B: STEP CONFIGURATION

COLUMNS	FORMAT	VARIABLE	EXPLANATION
1-10	F10.0	R(1)	Height of first riser
11-20	F10.0	B(1)	Length of first tread
21-30	F10.0	R(2)	Height of second riser

This is repeated until complete step geometry has been specified. More than one physical card may be required.

		B(NS)	Length of last tread
		R(NS+1)	Height of last riser

APPENDIX

CARD 2

COLUMNS

(31-40) Tolerance used in Southwest Research Test Programs was (.025)

(41-50) Number of iterations used in Southwest Research Test Programs was (20)

(51-60) Number of stations for Southwest Research Programs was either (31) or (61). 61 being primarily for single lap and 31 being primarily for double lap joints.

(71-80) K_e for Southwest Research Test Runs was (0.01) - single lap

(0.02) - double lap

(0.1) - step lap

CARD 3

COLUMNS

(31-40) ESC obtained from shear stress vs strain curve for adhesive where .7G line intersects the τ vs γ curve.

(41-50) n = shape factor, obtained from sheer stress-strain curve

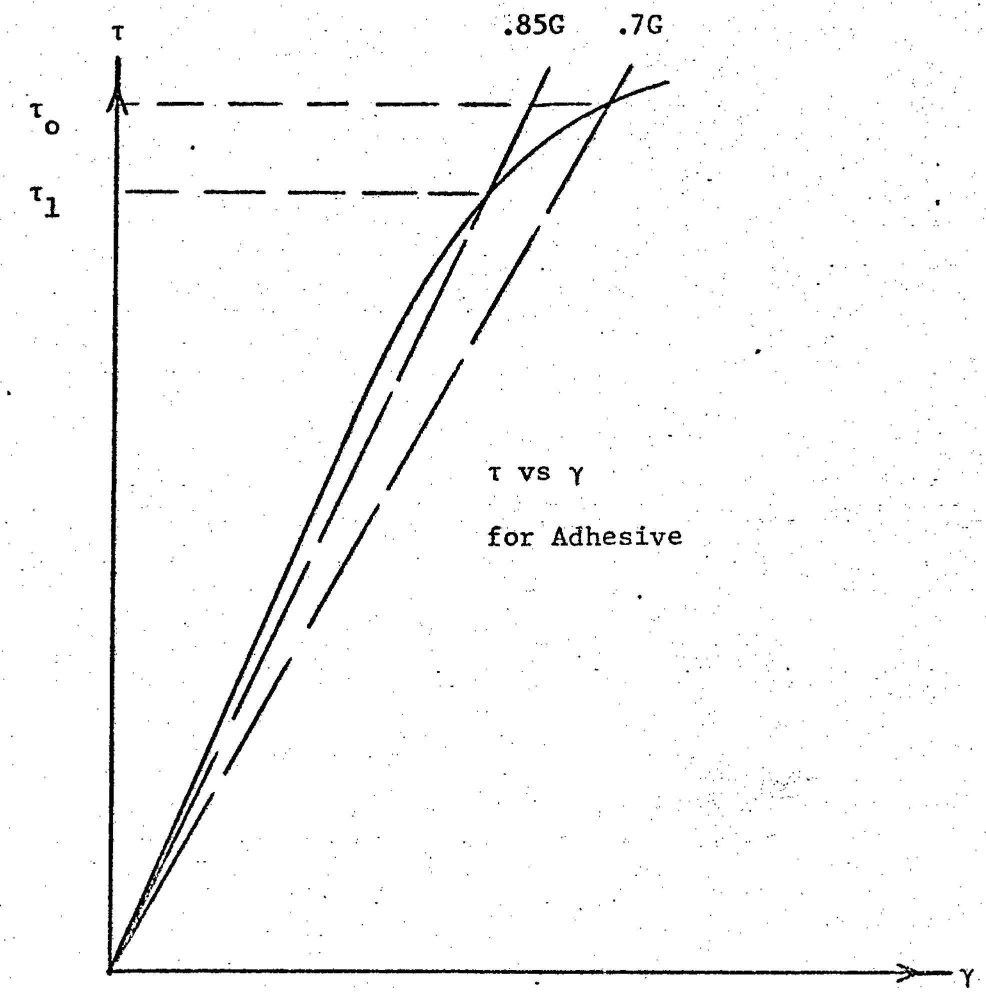
$$= 1 + \frac{\log_{10}(17/7)}{\log_{10}(\tau_o/\tau_1)}$$

where:

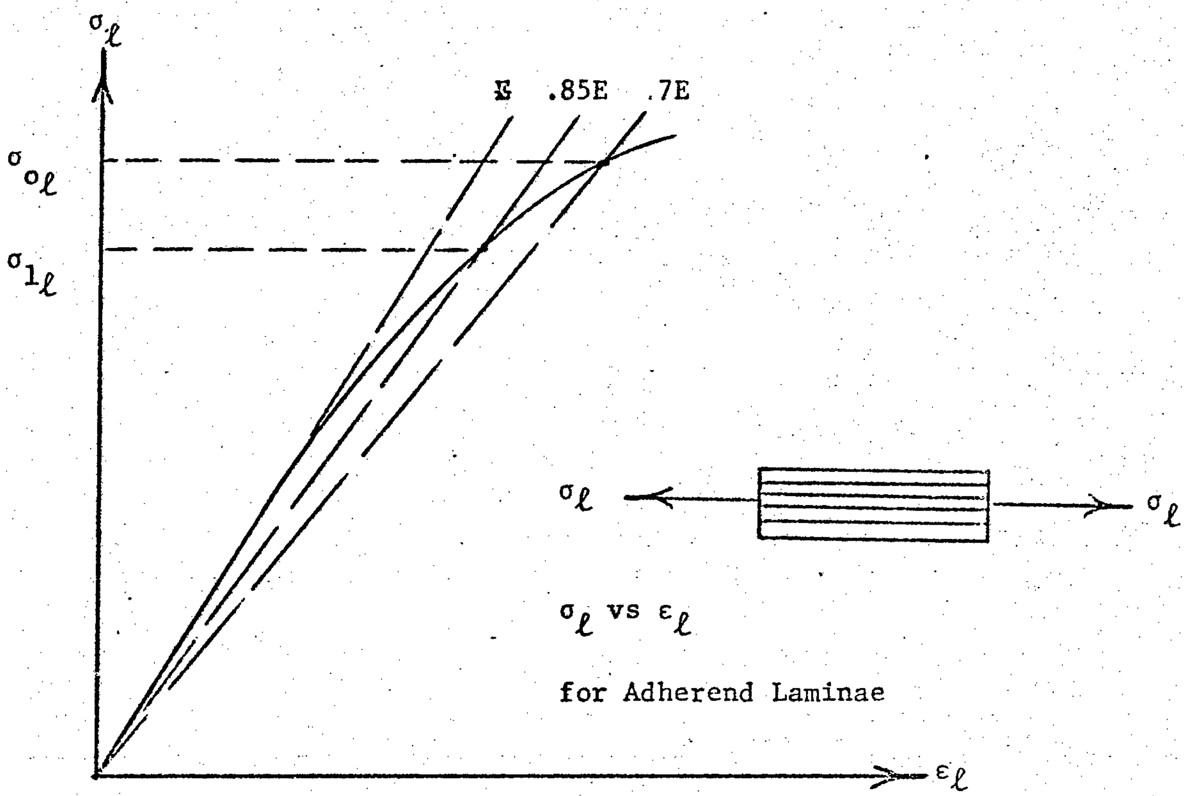
τ_o = stress at secant modulus - .7G = ESC

τ_1 = stress at secant modulus = .85G = ENC

Taken from shear stress-strain curve for adhesive


τ
.85G
.7G
τ_o
τ_1
τ vs γ
for Adhesive
γ

CARDS 5 & 6



To obtain E(1,1) - E_ℓ

$$E_\ell = \Delta_{\sigma_\ell} / \Delta_{\varepsilon_\ell}$$

To obtain ES(1,1) - σ_{o_ℓ}

σ_{o_ℓ} = Secant yield stress (stress at which the secant modulus = 0.7E)

NOTE: When the 0.7E secant modulus does not exist, the values to be used may be determined from the following formulae:

$$n = \frac{\mathrm{Log}_{10}\left(\frac{E\varepsilon' - \sigma'}{E\varepsilon'' - \sigma''}\right)}{\mathrm{Log}_{10}\ (\sigma'/\sigma'')}$$

$$\sigma_o = \frac{7}{3}\,(E\varepsilon'' - \sigma'')\,(\sigma'')^{-n}\ {}^{\frac{1}{1-n}}$$

Where σ', ε' and σ'', ε'' correspond to any two points on the stress strain curve.

<u>To obtain EN(1,1) - n_ℓ</u>

$$n_\ell = \text{shape factor} = 1 + \frac{\mathrm{Log}_{10}\ (17/7)}{\mathrm{Log}_{10}\ (\sigma_{o_\ell}/\sigma_{1_\ell})}$$

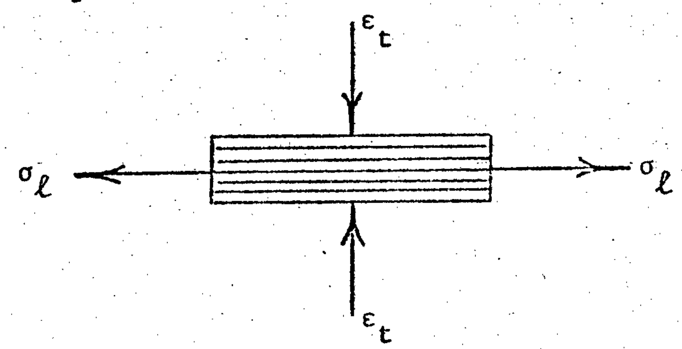
<u>From graph</u>:

σ_{o_ℓ} = stress at which the secant modulus = 0.7E

σ_{1_ℓ} = stress at secant modulus at 0.85E

<u>To obtain $E_{\ell t}$, $\sigma_{\ell t}$, $n_{\ell t}$</u>

σ_ℓ vs ε_t plot for adherend necessary

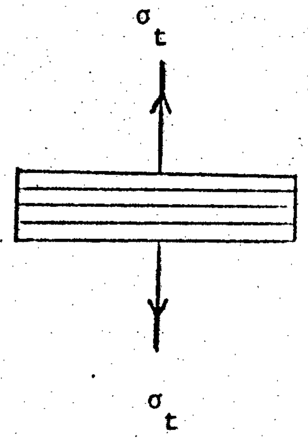


Then:

Analysis methods same as for E_ℓ, σ_{o_ℓ}, n_ℓ

<u>To obtain E_t, σ_{o_t} & n_t</u>

σ_t vs ε_t plot for adherend necessary

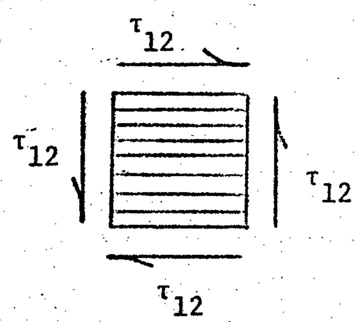


Then:

Analysis methods same as for E_ℓ, σ_{o_ℓ}, n_ℓ

<u>To obtain $G_{\ell t}$, $\tau_{o_{\ell t}}$, $n_{\ell t}$</u>

$\tau_{\ell t}$ vs $\gamma_{\ell t}$ plot for adherend necessary



Then:

Analysis methods same as for $E\ell$, σ_{o_ℓ}, n_ℓ

<u>CARD 10</u>

KFAIL =
1. Maximum stress = Allowable stress (for adhesive and isotropic adherends)**
2. Maximum strain = Allowable strain (for composite adherends)**
3. Von Mises stress = Allowable stress

** As used by SwRI, Ref. AFFDL-TR-72-97, see X. 2, p. 146